

EFFECTS OF ROAD TRAFFIC SAFETY MEASURES: A PRESENTATION OF THE TRAFFIC SAFETY HANDBOOK

by

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ABSTRACT

The third edition of the Norwegian Traffic Safety Handbook, was issued in 1997 (Elvik, Borger Mysen, Vaa 1997). The book gives a presentation of 124 road safety measures and covers measures in the following areas:

- 1. General purpose policy instruments (14 measures in total)*
- 2. Road design and road furniture (20 measures)*
- 3. Road maintenance (9 measures)*
- 4. Traffic regulation (21 measures)*
- 5. Vehicle design, vehicle equipment and personal injury protection (28 measures)*
- 6. Vehicle inspection (4 measures)*
- 7. Driver training and associated measures (13 measures)*
- 8. Public education and information campaigns (4 measures)*
- 9. Police enforcement and sanctions (11 measures)*

For each of the road safety measures, the handbook summarizes evidence from evaluation studies with respects to the effects of the measure on road safety. Whenever possible, effects are defined in terms of the percentage change in the expected number of accidents, or the expected number of injured at a certain level of injury severity. A distinction is made between fatal accidents, injury accidents, property-damage-only-accidents and accidents of unspecified severity. As far as injury severity is concerned, a distinction is made between fatal injuries, severe injuries and slight injuries. Most of the research that is summarised in the handbook has been reported in the OECD-countries, although the book also refers to some studies from Jordan, Malaysia, Nigeria, Pakistan, and Papua New Guinea.

The quality of the evidence presented in the book with respect to the effects of the measures on road safety does of course vary substantially, but, whenever possible, only evidence from methodologically strong studies has been presented. For some measures high quality research is available, for others the evidence can be poor. Meta-analysis has been applied in order to summarize evidence from individual evaluation studies for about 100 of the 124 measures. For all measures on which meta-analysis have been applied, a best estimate of the effect on the expected number of accidents and/or injuries, is calculated and presented.

In addition to presenting evidence concerning the safety effects of the measures, the handbook also gives information on selected issues as effects on mobility (travel time), effects on the environment, costs of implementing the measure and cost-benefit ratios.

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The paper will present some selected examples of the effects of road safety measures considered to be of relevance for the Africa T² 2001 Conference. The problem of transfer of this kind of knowledge, i.e. generalising effects from one traffic culture to another, will be discussed.

1. INTRODUCTION

The Institute of Transport Economics issued their first edition of the Norwegian Traffic Safety Handbook in 1982. During the years, the number of new effect studies on various traffic safety measures have been steadily increasing, new safety measures are invented, and better evaluation methods have been required. These are all factors that have justified updates of the Handbook. The second edition was issued in 1989, and the third and the most recent edition in December 1997 (Elvik, Borger Mysen, Vaa 1997). Rune Elvik has acted as author on all three editions and he has been the editor and main author of the third edition of the Handbook. Coauthors on the third edition have been Anne Borger Mysen and Truls Vaa. The number of measures that have been considered were 73 in the first edition, 84 in the second, and 124 in the third edition.

2. STRUCTURE OF THE HANDBOOK

The Handbook gives a presentation of 124 road safety measures and covers measures in the following areas:

1. General purpose policy instruments (14 measures in total)
2. Road design and road furniture (20 measures)
3. Road maintenance (9 measures)
4. Traffic regulation (21 measures)
5. Vehicle design, vehicle equipment and personal injury protection (28 measures)
6. Vehicle inspection (4 measures)
7. Driver training and associated measures (13 measures)
8. Public education and information campaigns (4 measures)
9. Police enforcement and sanctions (11 measures)

Most of the research that is summarised in the handbook has been issued in OECD-countries, although the book also refers to some studies from countries outside the OECD-area. These are Jordan, Malaysia, Nigeria, Pakistan, and Papua New Guinea. The number of effect-studies referred to and used in the Handbook is about 1700.

The 124 traffic safety measures were treated and grouped according to the 9 superior areas listed above. In this section, a complete list of all measures is presented. A best estimate of the effects of a single measure is calculated for about a 100 of the 124 measures. In the following list, the symbol (m) is used in cases where meta-analysis is applied when calculating a best estimate of the effect of the safety measure in question. The symbol (-) is used whenever the effect of the measure could not be estimated by meta-analysis, either because meta-analysis would not be an appropriate method for the measure in question, because no evaluation studies were found, or because there were too few results. (There is no specific lower limit with regard to the number of results below which meta-analysis is not appropriate, but 1-2 results is too few to produce a meaningful meta-analysis. In my opinion, at least 5 results are needed for applying meta-analysis.)

Part I, part II and each of the 9 chapters in part III ends with a list of the references that have been used in that specific part or chapter.

Part I – GENERAL

1. Background and Introduction

- Aim of the book
- Issues addressed in the book
- Structure of the book
- Role of Research in Traffic Safety Policy

2. The Preparation of *the Traffic Safety Handbook*

- Systematic literature search
- Criteria for study selection
- Classifying the studies
- The use of meta-analysis to summarize results
- Quality Control in the Traffic Safety Handbook

3. Accidents and Accident Risk in Road Traffic

- Rules for reporting of traffic accidents involving personal injury
- Reporting levels for traffic accidents involving personal injury in Norway and other countries
- Consequences of traffic injury for the quality of life
- Property-damage-only accidents
- Collective risk, but individual safety
- Changes in number of persons injured in traffic over time
- Traffic accident risk compared to other activities
- Traffic accident risk in Norway compared to other countries
- Factors affecting accident numbers and accident severity
- The relationship between traffic volume and accidents
- Accident risk and risk factors in road traffic
- Factors affecting injury severity

4. Basic Concepts of Safety Research

- Some basic problems in traffic safety research
- Do accidents have causes?
- Traffic accidents as a self-regulating problem:
- Theories of risk homeostasis and behavioral adaptation (risk compensation)
- Road users' security and insecurity: a multi-facetted problem
- The use of accident counts and accident rates to measure safety
- Principles for improving traffic safety

5. The Quality of Evaluation Studies

- What do we want to know?
- Methodological requirements and the basis for conclusions
- Characteristics of good evaluation studies
- Examples of shortcomings in evaluations studies
- The rating of studies in the Traffic Safety Handbook
- Which measures are well researched, and which, are less well researched?

6. Priority Setting and Policy Making

- Activities involved in policy making
- Alternative approaches to planning and policy making
- Alternative measures to solve different traffic safety problems
- Cost-benefit analyses - Accident costs
- Official priorities in road/transport policy
- OECD recommendations for planning and prioritizing traffic safety measures

PART II - GENERAL PURPOSE POLICY INSTRUMENTS (14 measures)

- Introduction and overview of 14 measures
- Organisational measures (-)
- Information for decision makers (-)
- Quantified targets and targeted road safety programmes (-)
- Local community programmes (m)
- Exposure control (m)
- Urban and regional planning (-)
- Road plans and road construction (-)
- Road safety audits (-)
- Vehicle taxation (-)
- Road pricing (-)
- Changing in the modal split of travel (m)
- Legal regulation of road traffic (m)
- Legislative regulation of commercial transport (m)
- Provision of medical services (-)

PART III – SPECIFIC TRAFFIC SAFETY MEASURES (110 measures)

1. Road Design and Road Installations (20 Measures)

- Introduction and overview of 20 measures
- Pedestrian and bicycle tracks, cycle paths and sidewalks (m)
- Motorways (m)
- Bypasses (m)
- Main roads and arterial roads into urban areas (m)
- Channelization of intersections (m)
- Roundabouts (m)
- Improving geometric design of intersections (m)
- Staggered junctions (m)
- Grade-separated interchanges (m)
- Black spot treatment (m)
- Cross section design (m)
- Roadside safety measures (m)
- Alignment and sight distance (m)
- Rehabilitation of existing roads (m)
- Guard rails and crash cushions (m)
- Game accident treatments (m)
- Safety treatment of horizontal curves (m)
- Road lighting (m)
- Improving safety in tunnels (m)
- Rest stops and service areas (-)

2. Road Maintenance (9 Measures)

- Introduction and overview of 9 measures
- Resurfacing (m)
- Improvement road surface smoothness (m)
- Improvement road surface friction (m)
- Bright road surface (-)
- Securing roads against landslides and avalanches (-)
- Winter maintenance of roads (m)
- Winter maintenance of pedestrian and bicycle areas (m)
- Upgrading poor sign information (-)
- Warning of road works (m)

3. Traffic Control (21 Measures)

- Introduction and overview of 21 measures
- Area-wide traffic calming (m)
- Environmentally adapted through roads (m)
- Pedestrian streets (m)
- Woonerfs, urban play streets (m)
- Access control (m)
- Priority control (m)
- Yield signs at intersections (m)
- Full stop at intersections (m)
- Traffic signal control (m)
- Signalized pedestrian crossings (m)
- Speed limits (m)
- Speed reducing devices (m)
- Road markings (m)
- Traffic control for pedestrians and cyclists (m)
- Parking regulations (m)
- One-way streets (m)
- Reversible lanes (m)
- Bus lanes and bus stop design (m)
- Dynamic route guidance (-)
- Variable signs (m)
- Securing railroad-highway grade crossings (m)

4. Vehicle Design and Protective Devices (28 Measures)

- Introduction and overview of 28 measures
- Tire thread depth (m)
- Studded tires (m)
- ABS and disc brakes (m)
- Extra high-mounted stop lamps (m)
- Daytime running lights for cars (m)
- Daytime running lights for mopeds and motorcycles (m)
- Improving automobile headlights (-)
- Reflective materials and protective clothing (-)
- Steering, suspension and vehicle stability (-)
- Cycle helmets (m)
- Motorcycle helmets (m)

- Seatbelts in passenger cars (m)
- Child restraints (m)
- Airbags in passenger cars (m)
- Seatbelts in buses and trucks (-)
- Vehicle crashworthiness (m)
- Driving control stalks and instruments (-)
- Intelligent cruise control (-)
- Regulating vehicle mass (weight) (-)
- Regulating automobile motor power and performance speed (-)
- Regulating motor power of mopeds and motorcycles (-)
- Under ride protection on trucks (-)
- Safety equipment on trucks (m)
- Moped and motorcycle equipment (m)
- Bicycle safety equipment (m)
- Safety standards for trailers and caravans (-)
- Fire safety standards (-)
- Hazardous goods regulations (-)

5. Vehicle and Garage Inspection (4 Measures)

- Introduction and overview of 4 measures
- Compliance control for vehicle safety standards (m)
- Periodic motor vehicle inspections (m)
- Road-side vehicle inspection (m)
- Garage regulation and inspection (-)

6. Driver Requirements, Driver Training and Professional Driving (13 Measures)

- Introduction and overview of 13 measures
- Driving license age limits (m)
- Health requirements for drivers (m)
- Drivers' knowledge and proficiency requirements (m)
- Basic automobile driver training (m)
- Treatment of problem drivers (m)
- The automobile driving test (-)
- Training and testing moped and motorcycle operators (m)
- Training and testing professional drivers (m)
- Graduated driving licenses and driving restrictions (m)
- Motivation and incentive systems in the workplace (m)
- Regulation of professional drivers' driving and rest hours (-)
- Safety requirements for drivers of emergency service vehicles (-)
- Safety requirements for school transport (-)

7. Traffic Education and Information (4 Measures)

- Introduction and overview of 4 measures
- Education of pre-school children (-)
- Education in the schools (-)
- Road user information and campaigns (m)
- Variable feedback signs (m)

8. Enforcement and Sanctions (11 Measures)

- Introduction and overview of 11 measures

Stationary speed enforcement (m)
Patrolling (m)
Blood-alcohol-concentration regulations (m)
Drinking-and-driving enforcement and measures against recidivism (m)
Seat-belt enforcement (m)
Automatic speed enforcement (m)
Red-light cameras (m)
Simple traffic tickets (-)
Fines and prison sentences (m)
Warning letters, penalty points and driving license withdrawal (m)
Motor vehicle insurance (m)

Part IV: DEFINITIONS, GLOSSARY OF TERMS, SUMMARIES, INDEX

Definitions and explanation of terms
Summaries and symbols
Index of subject headings

3. STRUCTURE OF CHAPTERS ADDRESSING SPECIFIC SAFETY MEASURES

In addition to presenting evidence concerning the safety effects of the individual measures, the book also gives other relevant information. Each of the chapters dealing with a safety measure has a standard layout consisting of the following sections:

1. Description of traffic safety problem the measure is intended to affect
2. Description of the measure – (and its current use in Norway)
3. Effects on accidents
4. Effects on mobility (travel time)
5. Effects on the environment
6. Costs of implementing the measure
7. Cost-benefit analysis
8. Formal responsibility – and the decision making process

This standard procedure also results in a standard layout of all individual chapters addressing the 124 traffic safety measures. The sections dealing with effects on mobility and on the environment have been included because decisions concerning the use of various traffic safety measures are strongly influenced not just by their safety effects, but also by their effects with respect to other policy objectives.

4. ASSESSING THE EFFECTS OF THE SAFETY MEASURES

For each of the traffic safety measures, the handbook summarizes evidence from evaluation studies with respect to the effects of the measure on road safety. Whenever possible, effects are defined in terms of the percentage change in the expected number of accidents, or the expected number of injured at a certain level of injury severity. A distinction is made between fatal accidents, injury accidents, property-damage-only-accidents and accidents of unspecified severity. As far as injury severity is concerned, a distinction is made between fatal injuries, severe injuries and slight injuries. The quality of the evidence presented in the book with respect to the effects of the measures does of

course vary substantially, but, whenever possible, only evidence from methodologically strong studies has been presented. For some measures high quality research is available, for others the evidence can be poor. As mentioned, meta-analysis has been applied in order to summarize evidence from individual evaluation studies for about 100 of the 124 measures. For all measures on which meta-analysis have been applied, a best estimate of the effect on the expected number of accidents and/or injuries, is calculated and presented.

5. ABOUT META-ANALYSIS

The basic entity of a meta-analysis is a *result*. By a *result*, for example from an evaluation study, is meant an estimate of the change in the number of accidents, accident risk, number of injuries, or injury risk. Meta-analysis may be described as a procedure for summing up all the individual results from different studies about the same measure, by a weighted average. The weights of each of the results are calculated in such a way that the statistical uncertainty in the weighted average is minimised. The weights in turn depend on the accident counts, which means that the more accidents an individual result is based on, the higher is the statistical weight of that result (Delhomme et al 1999).

The formulas for converting accident counts to a mean effect is the following (see Fliess, 1981 for the rationale):

The effect of any given study was calculated by converting the accident numbers into a log-odds ratio. Meta-analysis proceeds from steps 1 through 4 for every single study that contains appropriate accident numbers. The steps are:

1. Calculation of odds ratio:

$$\text{odds ratio (effect)} = \frac{\frac{\text{After}_{(T)}}{\text{Before}_{(T)}}}{\frac{\text{After}_{(C)}}{\text{Before}_{(C)}}}$$

where:

After_T = Accident numbers in after-period – treatment group
 Before_T = Accident numbers in before period – treatment group
 After_C = Accident numbers in after-period – control group (if any)
 Before_C = Accident numbers in before-period – control group (if any)

2. Calculation of weights: $\text{Weight} = 1/(1/B_T + 1/A_T + 1/B_C + 1/A_C)$
3. Calculation of log-odds * weight: $\text{Ln (effect)} * \text{weight}$. Having done the calculations for all single studies, meta-analysis proceeds through step 4.
4. For all studies 1 n, the weights are summed up: $\sum \text{Weights}_1 \dots n$
 For all studies 1n, the product $\sum \text{Ln(effects)} * \text{weights}_1 \dots n$ is summed up across all studies

The overall effect, i.e. across all studies 1 n, is then calculated and given by the following formula:

$$\text{Overall effect} = e^{\sum (\text{Ln(effects)} * \text{weights}) / \sum \text{weights}}$$

For every measure where a meta-analysis could be properly applied, a best estimate of the effects of the measure on the number of accidents is presented in a standardised table layout together with a 95% confidence interval.

6. TRANSFER OF KNOWLEDGE

Transfer of technology requires transfer of knowledge. The Traffic Safety Handbook should represent knowledge that has a potential as an instrument and a knowledge base for improving traffic safety in Tanzania and other African countries. There is, however, one major problem with this transference of knowledge. That is the question of validity: Would this kind of knowledge, developed for the most in the countries of Western Europe, Canada, USA, Australia and New Zealand, obtain the same effects in less motorised countries as in African countries? Mohan and Tiwari (2000) specifically address this important question:

“Road safety policies in highly motorised countries (HMC) have evolved over the last fifty years with input from research and academic institutions. However, such efforts have not gone into solving problems of road safety in less motorised countries (LMC). The traffic patterns, modal shares and accident patterns in LMCs differ significantly from those obtaining in HMCs. These patterns have not been experienced in the past by HMCs and so technologies and policies cannot be directly transferred from HMCs to LMCs without modifications. Basic principles of epidemiology and road safety need to be used to develop road safety policies suited for LMCs. “ (Mohan and Tiwari 2000, page 155)

I share this view. Almost all of the effect-studies used in the handbook, and which serve as input to the meta-analysis, are done in highly motorised countries. Hence, the estimates of effects of measures represent HMCs only. What then about the implementation of the measures in less developed countries? Would traffic safety measures have the same effects, lower effects, higher effects or no or adverse effects if applied in LMCs? I cannot tell. What is needed is that less motorised countries do their own evaluations when traffic safety measures are implemented in such countries.

7. EFFECTS OF TRAFFIC SAFETY MEASURES – SOME SELECTED EXAMPLES

Considering traffic safety measures that possibly could be of some relevance to less motorised countries, there is, however, one basic fact that would apply to all traffic cultures world-wide: The level of violence that the human body can tolerate, i.e. the physical forces that act on the human body in car crashes, car against car, or car against vulnerable road users, the “delta-v’s” that the human body can resist in accidents where speed and sudden speed-change is a part of the picture. In a study by Anderson et al (1996) it is found that the level of survival for pedestrians at impact speeds of 30 km/h or below is nearly 100 % while it is estimated to be zero at impact speed of 60 km/h or more. This means that any safety measure aiming at separate vulnerable road users from vehicles would be highly beneficial for the survival rate of for example pedestrians when the travel speeds of vehicles exceeds 30 km/h.

Accident statistics from 1995 show that the road user groups that have the highest fatality losses are ‘passengers’ and ‘pedestrians’ (Assum 1998). In Tanzania in 1995 41% of all fatalities were ‘passengers’ and 40 % were pedestrians. In Kenya, also in 1995, the corresponding numbers of fatalities were 34 % and 44 %. (It is supposed that the group ‘passengers’ comprise passengers both in personal vehicles and passengers on public service vehicles, but also that it is the latter group of passengers that is the major one). Hence, any measure that specifically addresses these two groups would have the largest potential of reducing the number of fatalities and injuries.

I have selected three safety measures as examples from the meta-analysis of effects-studies. I admit that my experience with road traffic and traffic safety problems in African countries is scarce, but I hope that the following three examples could be of some relevance:

- Effects of pedestrian crossings
- Effects of road lighting
- Effects of blood-alcohol-concentration legislation

The effects of ordinary and elevated pedestrian crossings is presented in table 1:

Table 1: Effects on accidents of pedestrian crossings. Percentage change in the number of accidents (results from meta-analysis of effect-studies. (Source: Elvik et al 1997)

Accident types affected		Best estimate	95% confidence level
<i>Ordinary pedestrian crossing</i>			
Personal injury accidents	Accidents with pedestrians	+28	(+19; +39)
Personal injury accidents	Vehicle accidents	+20	(+5; +38)
Personal injury accidents	All accidents	+26	(+18; +35)
<i>Elevated pedestrian crossing</i>			
Personal injury accident	Accidents with pedestrians	-49	(-75; +3)
Personal injury accident	Vehicle accidents	-33	(-58; +6)
Personal injury accident	All accidents	-39	(-58; -10)

While ordinary pedestrian crossings increase the number of accidents with 26 %, elevated crossings do quite the opposite, and even more so: The best estimate across all accident types is a 39 % reduction in the number of accidents, and the number of accidents with pedestrians is reduced with about 50 %. All reductions in table 1 are statistically significant. The number of effect-studies concerned with ordinary pedestrian crossings are 13 in total: 6 from United Kingdom, 2 from Canada, 1 from Sweden, 1 from Norway, 1 from Denmark, 1 from USA, and 1 from Australia. For elevated pedestrian crossings the numbers are 4 in total: 1 from Denmark, 1 from United Kingdom, 1 from Pakistan and 1 from Norway (Elvik et al 1997).

Table 2 presents the effects of road lighting - compared to a before-period with no lighting:

Table 2: Effects on accidents of road lighting. Percentage change in the number of accidents (results from meta-analysis of effects-studies. (Source: Elvik et al 1997)

Accident types affected		Best estimate	95% confidence level
Fatal accidents	Accidents in darkness	- 64	(- 74; - 50)
Personal injury accidents	Accidents in darkness	- 28	(- 32; - 25)
Property-damage-only-acc.	Accidents in darkness	- 17	(- 21; - 13)

The effects of road lighting are large, table 2 shows a 64 % reduction in the number of fatal accidents in darkness. For personal injury accidents and property-damage-only accidents the reductions are smaller, but still statistically significant. The results are based on 38 effects studies in total: 14 from USA, 8 from United Kingdom, 4 from Sweden, 3 from Australia, 3 from Denmark, 2 from Switzerland, and 1 from each of the countries Japan, Finland, Israel and Germany.

Table 3 presents the last example, i.e. the effects of blood-alcohol-concentration legislation including *per se* laws against drunken driving (the legislation implies that a certain level of blood-alcohol-concentration is stated):

Table 3: Effects on accidents of blood-alcohol-concentration legislation. Percentage change in the number of accidents (results from meta-analysis of effects-studies. (Source: Elvik et al 1997)

Accident types affected		Best estimate	95% confidence level
All accidents	All	- 4,5	(- 5,4; - 3,5)
Fatal accidents	Accidents in darkness	- 26	(- 28; - 24)
Personal injury accidents	Accidents in darkness	- 3	(- 4; - 2)
Fatal/personal injury acc..	Nighttime/single accidents	- 13	(- 14; - 11)

Table 3 shows that legislation and laws against drunken driving have a large effect in fatal accidents with a reduction in the number of accidents of 26% and a reduction in night-time and single vehicle accidents of 13 %. The effects on personal injury accidents only, and on all accidents in total, are in the range of 3-5%. All effects shown in table 3 are statistically significant (Elvik et al 1997).

8. CONCLUSION

The Norwegian Traffic Safety Handbook considers 124 traffic safety measures. Of these, about 100 have been evaluated in terms of their effects on accidents. Meta-analysis is considered to be a fruitful procedure for summing up results from different studies about the same measure, by a weighted average that can serve as a best estimate of the effects of the measure in question.

The Traffic Safety Handbook should be a knowledge base for improving traffic safety in Africa. There is, however, one problem concerning the generalisation of results as most of the evaluations studies have been done in highly motorised countries. What is needed is that less motorised countries do their own evaluations when traffic safety measures are implemented.

One basic fact that should, however, apply to all traffic cultures: The level of violence that the human body can tolerate is constant throughout all countries, and this tolerance is also limited. As mentioned, the level of survival for pedestrians at impact speeds of 30 km/h or below is nearly 100 % while it is close to zero at impact speeds of 60 km/h or more. Hence, any traffic safety measure aiming at separating vulnerable road users from vehicles would be highly beneficial for the survival rate of for example pedestrians. Building bypass-roads leading through-traffic outside villages and densely populated areas should be effective in reducing the number of accidents involving vulnerable road users. The same should apply also to any measure aiming at reducing travel speeds to levels that the human body may tolerate in cases of traffic accidents.

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